Thermodynamic potential for the abiotic synthesis of nucleobases, ribose, and deoxyribose under submarine hydrothermal conditions

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Common to all organisms, ribose, deoxyribose, and the five common nucleobases (or, nucleic-acid bases) are constituent molecules of nucleotides, which are involved in the storage (DNA) and transmission (RNA) of genetic information. They serve as bioenergetic intermediates (ATP, GTP), oxidation-reduction couples (NAD and NADP) and are central to polysaccharide synthesis (UDP). Because these molecules are essential to so many basic metabolic functions, documenting the range of fluid compositions and chemical potentials required to generate and stabilize nucleobases and (deoxy)ribose is crucial to better understanding conditions that were conducive for the emergence and early evolution of life.

Due to the high chemosynthetic potential created by fluid mixing in extant hydrothermal systems and the relatively close phylogenetic relationship that many thermophilic organisms might have with the last common ancestor, numerous experimental and theoretical studies have explored the role that submarine hydrothermal environments may have had in hosting the origin of life. In this study, we have quantified the thermodynamic potential for the abiotic synthesis of nucleobases (adenine, cytosine, guanine, thymine, and uracil), ribose, and deoxyribose as a function of temperature, pressure, and bulk fluid composition using formaldehyde and HCN as precursor building-block molecules. Under low concentrations of these precursors and for a wide range of temperature and pressure conditions, favorable thermodynamic conditions are established for the abiotic synthesis of ribose, deoxyribose and all of the common nucleobases except thymine. A thermodynamic description and interpretation of the biogeochemical reactions involved in these pre-biotic processes can be used to design experimental investigation of the abiotic synthesis nucleic-acids and related biomolecules.

The Paleocene volcanic succession in West Greenland: Compositions, volumes, and mantle sources

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The Paleocene volcanic succession on Disko and Nuussuaq in West Greenland consists of up to 2 km of of mainly picrites with on average 15.7 wt% MgO (the Vaigat Formation, VF) overlain by up to 2 km of tholeiitic flood basalts with on average 6.5 wt% MgO (the Maligât Formation, MF) (MgO in uncontaminated rocks). The whole succession has been dated at 62–60 Ma, with no measurable time lapse between the two formations.

The picrites of the VF represent unfractionated or slightly fractionated primary magmas, whereas the basalts of the MF are three-phase cotectic and distinctly fractionated. About 5% of the VF and 40% of the MF lavas are contaminated by sediments in high-level crustal magma chambers. Contaminated rocks usually form separate volcanic units, and except for the upper part of the MF, uncontaminated rocks abound.

REE patterns for uncontaminated rocks of both formations are consistently convex-up with La_N/Nd_N= 0.6–1.1 and Gd_N/Lu_N = 1.3–2.7. Simple REE melting modelling suggests similar to slightly lower degrees of melting for the MF basalts compared to the VF picrites.

The magmas of both formations were derived from a uniform asthenospheric mantle source which was geochemically and isotopically depleted. Uncontaminated magmas have $^{87}Sr/^{86}Sr(i)$= 0.70294–0.70344, $^{143}Nd/^{144}Nd(i)$= 0.51291–0.51308, and $^{206}Pb/^{204}Pb(i)$= 17.51–17.99. Two units in the VF and some scattered lavas in both formations show various ‘enriched’ geochemical signatures and are considered to be contaminated during their passage through the lithospheric mantle with metasomatised areas there.

Based on the measured lava volumes on Disko and Nuussuaq, extrapolation to the whole region, and consideration of the amount of fractionation and estimated degrees of melting, the total volume of mantle involved in the generation of the Paleocene volcanic succession in West Greenland is 550,000 km^3. With a ‘rift’ length of 300 km and a width of the productive areas of max. 50 km, the involved mantle prism was min. 37 km deep. This volume of uniform and hot mantle is best envisaged as part of a mantle plume.

Convex-up REE patterns are uncommon in LIPs. They would be produced by melting of a depleted mantle in garnet facies under a thick lithospheric lid and would occur on the broken-up margins of thick cratons such as Precambrian ones. In the North Atlantic region they occur along the periphery of the suggested mantle plume but not in the centre.